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REPORTS OF THE AD HOC PANELS

CONTRIBUTION OF TECHNOLOGIES, INCLUDING NEW AND EMERGING TECHNOLOGIES, TO INDUSTRIALIZATION IN DEVELOPING COUNTRIES

Strengthening of Linkages between the National Research and Development Systems and Industrial Sectors

Report of the Panel of Experts

Economic and Social Council resolution 1993/69 decided to form an *Ad Hoc* Panel of Experts to study in depth the various issues related to the substantive theme of the first session of the Commission and the report of the Secretary-General on the contribution of technology to industrialization and regional integration (E/CN.16/1993/2). The report of that Panel is submitted to the Commission for its consideration.

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EXECUTIVE SUMMARY

1. The Report of the Secretary-General on the Contribution of Technology to Industrialization and Regional Integration (E/CN.16/1993/2) had found that, although scientific and technological development constituted one of the key sources of industrial development and competitiveness, most developing countries and countries in transition had a poorly developed technological infrastructure and weak linkages between their research and development (R&D) systems and the productive sectors of their economies. As a follow-up to this report, the Panel of Experts on the Contribution of Technologies, including New and Emerging Technologies, to Industrialization in Developing Countries, created by the Commission on Science and Technology for Development, examined ways and means of enhancing the contribution of R&D to industrialization in developing countries and countries in transition.

2. In view of recent shifts in the global technological and competitive environment, the Panel decided to take a fresh look at R&D policies in developing countries and countries in transition. The Panel agreed that the R&D systems in most developing countries and countries in transition were not in a position to upgrade the industrialization process in their respective countries. A number of common weaknesses characterized these systems: (a) levels of R&D expenditure were extremely low compared to that in industrialized countries; (b) the enterprise sector -- the main user and producer of innovations resulting from R&D -- did little or no R&D itself; (c) any public-sector R&D taking place was normally fragmented and insufficiently oriented towards the needs of industry; (d) publicly funded research and development institutes (RDIs) had not been successful in generating a sufficient volume of commercially applicable innovations arising from their activities; (e) in RDIs, there was a disproportionate emphasis on basic rather than applied research; (f) scientists in RDIs tended to be more concerned with producing publications than with the needs of industry; (g) appropriate incentives for the inducement of R&D were generally lacking. Although most of these weaknesses were found to be common to both developing countries and to the countries in transition, the Panel nevertheless believed that the situation facing the two groups of countries differed insofar as developing countries had a more articulated market mechanism favouring commercialization of R&D results, whereas the countries in transition were better endowed with scientists and engineers able to carry out R&D.

3. The Panel agreed that acquisition, development and use of technology formed part of a learning process involving interactions among many different agents in the S&T system, including the enterprises themselves as leading agents. The lack of such interactions in developing countries and countries in transition was related to the low level of technological capability that characterizes their industrial sectors.

4. The Panel recognized that intervening in favour of technological capability-building was a contentious issue. While the upgrading of technological capabilities clearly required government intervention in order to strengthen linkages between national R&D systems and productive sectors, the object of such intervention should be to provide the necessary incentives for investment in R&D and technological innovation. The Panel agreed to base its discussion on three main issues: (a) the enabling environment for R&D and technological innovation; (b) transforming public RDIs; and (c) stimulating enterprise-based R&D.

5. The Panel considered that R&D policies could be successful only if they were formulated as part of an overall coherent strategy aimed at the development of scientific and technological capabilities.

6. The Panel affirmed that the development of technological capabilities, in general, and R&D capabilities, in particular, was a process that was highly sensitive to the economic **environment** within which enterprises operated. Economic stability, steady growth in demand and adequate credit facilities were a

prerequisite to investment in R&D by enterprises. A market environment with a well-functioning price system, adequate physical infrastructure and education system was necessary for the development of technological capabilities consistent with economic efficiency.

7. With respect to the **transformation of R&D institutes**, the Panel made two types of recommendations relating to (a) increased commercialization of R&D activities, and (b) refocusing of RDIs' activities to make them more responsive to the needs of industry. The Panel suggested that RDIs -- in order to re-orient themselves and become more demand-driven institutions -- might offer to industry, in addition to traditional R&D-type services, various support and extension services.

8. It was agreed that greater **commercialization of R&D activities** would help to increase the amount of financial resources available to RDIs, thereby permitting them to carry out a larger volume of work. Furthermore, such a step would improve their effectiveness by subjecting their work to a market test. More importantly, the resulting interaction with enterprises would have a positive effect on various dimensions of their technological capabilities. Related to this point, the Panel believed that RDI activities could be refocused in a number of ways which might increase their relevance to industry. This would imply going beyond basic research. RDIs should give increased emphasis to providing **extension services** to existing industries and to less technologically advanced firms within those industries -- typically small and medium-sized enterprises (SMEs). These services would include "trouble-shooting", small process and product modifications, industrial engineering and design as well as other efforts aimed at adaptation and diffusion of imported technology. A number of **supporting services** could also become an important function of RDIs insofar as these were not carried out separately by other institutions. These would include, *inter alia*, the establishment of industrial standards, provision of quality control, certification and testing, detection of market trends and developments, assistance in the search for suppliers of inputs, partners, and R&D collaborators, training of personnel, provision of technical information, patent searches, etc.

9. The Panel believed that one of the important results of such a redirection of RDIs' functions would be to help the industries of developing countries and countries in transition meet the international competitive challenges that they increasingly faced at a time of rapid technological change at a global level.

10. However, the Panel wished to stress that the commercialization and redirection of RDI activities did not imply the elimination of R&D work on generic technologies such as electronics and mechanical engineering, which were of a long-term strategic interest to industry as a whole and which would not likely be undertaken without public funding. The Panel did not take a firm position on the percentage share of the RDI budget that should originate from commercially oriented activities. The extent to which RDIs generate revenues from the enterprise sector depends on the perceived usefulness of their activities by that sector in each country setting.

11. It was recognized that changes would have to be accompanied by a **modification in organizational structures** of RDIs, including in staffing, management and division of responsibilities and possibly the creation of separate, decentralized units outside existing RDIs. In this connection, the Panel underscored the need to study the successful experiences of a number of RDIs in industrialized and more advanced developing countries and countries in transition.

12. It was also noted that **universities** could play a complementary role to that of RDIs, particularly as regards specialized expertise in certain areas of interest to industry. Although cooperation between universities and enterprises was to be encouraged, the Panel nevertheless believed it needed to be monitored in order to avoid undue distraction of university staff from their primary

academic functions. Thus the establishment of independent business-oriented research units associated with, but functionally separate from, university faculties was preferable.

13. With respect to the **strengthening of R&D in the enterprise sector**, the Panel voiced broad support for the promotion of R&D and related innovative activity in this sector. The reasons for doing so were twofold. First, since government resources for funding of RDIs in developing countries and countries in transition were limited and inelastic, enterprises would necessarily have to play an increasing role in raising the present levels of spending on R&D. Secondly, the carrying out of R&D by enterprises themselves would increase the likelihood that it responded to their own needs as identified in the market. Moreover, the interface between R&D and productive activity called for in-house capabilities, enabling enterprises to respond quickly to changing demand conditions.

14. The Panel acknowledged the need to induce R&D activities in the enterprise sector through the use of both general and specific public policy measures. **General measures** would include, *inter alia*, tax and credit incentives, levies, subsidies such as loan guarantees, subsidized R&D services or inputs, duty exemptions on imported equipment and other inputs used in R&D activity, preferential treatment of local enterprises in the award of contracts and tariff exemptions. Governments could also play a catalytic role in the provision of research fellowships for scientific and engineering personnel in industry and other research opportunities for scientific personnel, such as study and work abroad.

15. The Panel considered that the advantages of the general measures resided in their administrative simplicity which permits the use of general criteria requiring little, if any, administrative discretion. Their disadvantages lay in the fact that since the measures were available to broad groups of enterprises indiscriminately, their cost, in terms of diverted resources, could be quite high.

16. **Selective measures** to promote enterprise-based R&D involved the targeting of particular industries and even firms within industries which the government might wish to promote. They could include the general measures noted above or other types of preferential treatment for particular firms or industries showing long-term growth potential. However, for such measures to work effectively, a system of continuous policy evaluation would be needed.

17. Selective measures had the advantage of concentrating resources on those industries perceived to have the most promising growth potential, viability and competitiveness. Their disadvantages related to the costs and inefficiencies stemming from a lack of knowledge and administrative competence required to make sound decisions.

18. The growing tendency worldwide for firms to cooperate technologically with their suppliers, customers, competitors, universities and research centres drew the attention of the Panel. It was agreed that developing countries and countries in transition would be well advised to encourage and facilitate R&D and other forms of technological cooperation among these actors as integral elements of their broader science and technology policies.

19. In this respect, governments had an important role to play as a sponsors through the promotion of cooperative joint ventures, strategic alliances, industry associations, clubs of RDI clients, etc. The general approach to such promotion could involve making the various types of R&D incentives conditional upon inter-firm cooperation on R&D.

20. The Panel noted the role of transnational corporations (TNCs) as agents of technological change in developing countries and countries in transition. In view of the growing knowledge and bargaining power of developing countries, the time

was now ripe for governments to assist enterprises in exploring strategic alliances with TNCs in the field of R&D and technological innovation. In this connection, there was a need for an appropriate enabling environment to encourage collaboration with those TNCs most likely to make a contribution to industrial development.

21. In its **Conclusions and recommendations**, the Panel affirmed that the main task of R&D efforts in the majority of developing countries and many of the countries in transition was to contribute to the transfer, adaptation and diffusion of imported technologies as part of an overall effort to upgrade domestic capacity to plan and carry out investments, operate and maintain production facilities, implement improvements in design and help market goods and services. It recommended to the Commission that it take up the following in its future work programme: examination of the relevance of the experiences of successful RDIs, for developing countries and countries in transition; exploration of the merits of alternative instruments for the promotion of enterprise-level R&D; the carrying out of national reviews of science and technology policy on a regular basis; and the study of the feasibility of establishing regional or sub-regional venture capital funds aimed at promoting technological innovation in industry.

INTRODUCTION

22. At its first session, the Commission on Science and Technology for Development analyzed the contribution which technologies could make, including new and emerging ones, to the industrialization of developing countries and the strengthening of regional and global integration processes, including proposals on ways and means of transferring such technologies and incorporating them into the productive sector of those countries (E/CN.16/1993/2). The report of the Secretary-General emphasized the need to integrate science and technology policies in developing countries. The aim was to ensure the upgrading of their scientific and technological base including strengthening of the linkages between the national research and development system and the private sector.

23. Subsequent to this report, ECOSOC, in its resolution 1993/69 of 30 July 1993, decided to form an *ad hoc* panel of experts, aided by the relevant organs, organizations and bodies of the United Nations system, to study in depth the various topics related to the substantive theme and the report of the Secretary-General, and concentrating on the following issues

(a) Policies and mechanisms for promoting linkages among national, subregional, regional and global science and technology systems and between them and the industrial sector of developing countries;

(b) Developing internal linkages within the United Nations system for effective coordination of the work dealing with the promotion of industrial development in developing countries;

(c) Past, present, and future trends in science and technology, including the transfer of technology and their implications for the sustainable industrial development of developing countries;

(d) Strategies for using science and technology in promoting exports in selected sectors;

24. In line with the above and with the purpose of focusing on a specific and clearly defined topic, it was decided to centre the work on:

Strengthening of linkages between national research and development systems and the industrial sector of developing countries

This emphasis could lend itself more easily to the identification of a set of practical proposals to the Commission on Science and Technology for Development. To this end, the Commission established the Panel of Experts on the Contribution of Technologies, including New and Emerging Technologies, to Industrialization in Developing Countries. The list of participants is annexed.

25. The Panel recognized the widely accepted view that a strong technological base was an essential component of competitive success in today's global economy and that this base would not likely emerge out of the isolated efforts of individual private producers or from the carefully organized efforts of a central government. Rather, successful national systems of innovation would probably comprise a complex web of private and public institutions operating through market and non-market relations and with varying degrees of competition and cooperation. Such complexity in the enabling environment for technological change would pose obvious problems to policy-makers searching for more successful research and development policies. In developing countries, these problems were further complicated by lack of skills and infrastructure, as well as the need to ensure the effective transfer of technologies -- originally designed for very different economic circumstances -- through effective channels between domestic and foreign producers.

26. The Panel attempted to assess the role and function of the national research and development apparatus, particularly in the context of global

liberalization and technology-based industrial competitiveness. It also sought to reassess public policy in research and development as a central component of science and technology policy and to propose ways and means of refocusing the research and development apparatus towards the needs of the economy. In most developing countries, as well as economies in transition, a key problem was how to refocus public research and development institutes towards more market-oriented activities aimed at enhanced technological capability of enterprises.

27. In addition, the Panel endeavoured to review appropriate policy initiatives aimed at the promotion of enterprise-based research and development through specific measures for stimulating research and development in this sector. In this context, the Panel discussed R&D and small and medium enterprises (SMEs), the role of government as promoter, the creation of venture capital companies, the role of intermediary institutions, university-business cooperation, and the impact of transnational corporations on R&D.

I. ENABLING ENVIRONMENT

28. It was pointed out early in the discussion that investment in R&D and in other types of innovative activities was highly sensitive to the economic and political environment. Certain conditions had to be fulfilled in order to reduce the inherent risks and uncertainties associated with investment in R&D and make it responsive to the needs of the industrial sector. These included, *inter alia*, (a) political and economic stability, (b) the existence of competition and market incentives, (c) a critical mass of scientists, engineers and technicians, (d) an adequate physical infrastructure and (e) an enabling legal and regulatory framework. While such conditions were taken for granted in industrialized countries, several and/or all of these factors were often lacking in many developing countries and economies in transition.

29. The absence of political and economic stability had been a major obstacle to technological development in some countries. Prolonged civil war and insurgency had led enterprises to postpone or cancel new investment, thereby foregoing the technological upgrading that would have accompanied it. Indebtedness and erratic economic growth -- as occurred during the 1980s in Latin America and well into the 1990s in Africa -- had a similar effect by reducing the rate of return on invested capital. Economic instability in the form of inflation and uncertain movement in exchange rates makes it difficult for investors to take the long view, with the result that spending on new products and processes becomes riskier, while speculation and short-term profit-taking runs rampant. A lack of exposure to price or quality competition as a result of state or private monopolies or of prolonged trade barriers can reduce the pressure to improve productivity and product performance or explore new markets, thereby diminishing the need for R&D and other types of investment in technology. Alternatively, it could induce investment in technological improvements for the production of goods or services that would not ultimately be able to stand up to competition or contribute to genuine industrial development. Low levels of literacy and a scarcity of scientific, technical and managerial personnel in many developing countries have limited their capacity to absorb new technology; this has, in practical terms, diminished the possibility of engaging in industrial R&D. Lack of efficient telecommunications, reliable electrical power, good roads and port facilities, etc. and the absence of an enabling legal and regulatory framework reduced the ability to do business generally. They also lower the returns on investment by the enterprise sector and reduce the incentive to invest in technology.

30. As regards the legal and regulatory framework, the Panel acknowledged that lack of protection for intellectual property could discourage some TNCs from licensing their technology in certain sectors, such as pharmaceuticals and computer software, where they perceived a need for such protection order to preserve profit margins. In addition to these basic conditions, shortcomings

in other areas that influence the climate for investment generally -- such as well-functioning financial markets -- would also tend to impede investment in technology and R&D. Finally, many developing countries had not yet made the explicit political commitment to technological development necessary for making investment in technology and R&D attractive to enterprises.

II. TRANSFORMING R&D INSTITUTES

31. The Panel believed that the economic and technological conditions of the present decade imposed tougher requirements on enterprises to improve productivity and strengthen their competitiveness. Most developing countries had witnessed a reduction in their overall R&D budgets, while competitiveness was becoming increasingly innovation-based. The impact of these two simultaneous pressures called for new policy approaches.

32. Throughout the mid- to late-1960s, and in some cases earlier, numerous publicly funded RDIs had been set up in developing countries with the objective of building and strengthening the technological capacities and competitiveness of their industries by offering R&D services to the industrial sectors in these countries. Recent studies had indicated, however, that in many developing countries the R&D outputs generated by these institutes did not have sufficient commercial application and that, relative to the invested resources, their contribution to the enterprise sector had been only modest (UNIDO, 1979; UNCTAD, 1990).

33. RDIs that had contributed significantly to the industrial development of the countries concerned were singled out by the Panel. Among others, these included the Institute for Science and Technology (KIST) in the Republic of Korea; Central Metallurgical Research and Development Institute (CMRDI), Egypt; Instituto Mexicano de Investigaciones Tecnologicas (IMIT), Mexico; Instituto Centroamericano de Investigaciones Tecnologicas (ICAITI), Guatemala; Technological Research Institute (IPT), Brazil, and Instituto Nacional de Tecnologia Industrial (INTI), Cuba. Although all of these institutes excelled in scientific research, some had been more successful than others in transferring the R&D results to industrial activity. The experience of these well-functioning institutions and laboratories merited further study and examination. The Panel agreed that the picture described below, however, was typical of the majority of RDIs in most developing countries. Existing United Nations studies suggested low levels of contribution to industrial innovation by RDIs, thereby demonstrating the presence of a gap between R&D and the production sector in most developing economies (UNCTAD, 1979 and 1990, UNIDO, 1990 and 1994).

34. Weaknesses of the typical RDI in developing countries were identified: (a) RDI's research tended to be too isolated from the needs of the productive sector and lacking in sufficient commercial orientation; (b) RDI scientists tended to be more concerned with their publications' record rather than with their contributions to the performance of the enterprise sector; (c) an appropriate system of incentives to promote high-quality research was lacking (UNIDO, 1993; UNCTAD, 1990; Thulstrup, 1994); (d) obsolescent, hierarchical managerial structures hampered a free flow of information and knowledge diffusion; (e) erratic financing structures contributed to short-sighted orientation of the RDIs' activities.

35. In the view of the Panel, RDIs appeared to play a very minor role as sources of industrial innovation, particularly in those few technologically dynamic industries which tended to rely on their own in-house R&D units or similar capabilities through foreign technical cooperation and/or foreign consultants. The Panel noted the examples of Egypt, Germany and Switzerland in this regard.

36. Since the possibility of increasing the allocation of tax revenues for the funding of RDIs was limited, attention focused on how to improve the institutions' effectiveness. The Panel noted that the advantages and disadvantages of alternative policy instruments and approaches for improving their contribution to the industrial sector in developing countries had been discussed elsewhere (see, for example, UNCTAD, 1990; ESCWA, 1993). The challenge was to re-orient the activities of RDIs in order to increase their effectiveness in responding to the demands of the enterprise sector by enhancing their ability to respond to the technological requirements both of the domestic and global marketplace. In order to achieve the above objective, the Panel suggested that the transformation of RDIs be undertaken in three closely interrelated areas: (a) sources of funding and income, (b) scope of activities and (c) organizational structure. These three components of the restructuring process were interrelated; reform proposals ought to be considered on a case-by-case basis according to the varying degrees of development of the RDIs and the particular nature of their problems.

A. Nature and sources of funding and income

37. The proposed changes in the mode of financing of RDI activities ranged from financial incentives to privatization. The best way to increase RDI efficiency was to render such institutes more self-supporting, that is, by transforming them into para-statal, semi-independent or even autonomous institutions. This implied a change in the mode of financing of RDIs' budgets away from exclusive reliance on state funding, through the commercialization of R&D outputs and the provision of technical services. An illustrative example in this regard was found in Chile's Instituto de Investigaciones Tecnologicas (INTEC). As a result of the structural adjustment policies undertaken by the government, the sources of public funding began to decline in 1975, at which time INTEC began to look for alternative sources of revenues and to redefine its institutional role.

38. Previous UNCTAD studies have indicated that revenues from clients' fees would stimulate internal efficiency and improve demand orientation. This in turn could have positive feedbacks on the quality of services provided. Such stimulus could help to overcome supply bottlenecks, particularly the inability of the RDIs to retain qualified personnel (UNCTAD, 1990).

39. The Panel singled out some specific and general weaknesses of RDIs in the area of provision of technical extension activities as well as with respect to industrial liaison and technical information services. In order to improve the RDIs' effectiveness as channels for technology transfer and adaptation, their utility for the industrial sector could be greatly enhanced with the provision of technical extension services, seminars, workshops and other promotional activities in the enterprise sector. SMEs, in particular, would benefit significantly from the provision of such services on a contractual basis.

40. What degree of self-support versus public support would be recommended? Since RDIs fulfil a social function provided by the government, they should not be entirely privatized: certain of their functions, particularly those in the area of standard setting, metrology, etc. ought to remain in the public domain. A history of public funding of RDIs renders self-sufficiency an arduous task; hence the Panel considered it preferable that the transformation process be made gradual instead of resorting to outright privatization.

41. A system of appropriate incentives to stimulate quality research of both a pecuniary and non-pecuniary nature was also underscored. Besides permitting the RDI staff to earn consultancy fees or share in the institutes' income from such fees, other types of non-pecuniary incentives to researchers were considered relevant. More than a few international observers have noted a dearth of adequate system of incentives to encourage competitive research in developing countries (Thulstrup, 1994). The lack of monetary and non-pecuniary rewards for active researchers poses a serious impediment to the development of research

capabilities in developing countries.1/ Other types of incentives may be introduced in the area of quality control and improvement, such as credit to researchers in recognized journals, the granting of international patents, etc. aimed at stimulating quality research.

B. Nature and scope of RDI activities

42. The Panel agreed that the nature and scope of activities of RDIs in many developing countries could be adjusted to improve their contribution to industry. Making them, in part, self-financing would in itself help to achieve this aim. It would induce RDIs to orient their work beyond simply developing new products and processes towards activities for which, more generally, clients would be willing to pay. A cursory look at the work carried out by RDIs in various parts of the world suggests that they may be in a position to provide a fairly wide range of services that contribute to meeting industrial needs. The types of services that could, in principle, be performed by RDIs -- depending on their capacities and resources as well as industry needs -- fell under the following headings: (a) industrial extension, (b) supporting services, (c) training, (d) R&D in the classic sense and (e) industrial promotion.

43. The most critical contribution that "transformed" RDIs could make was in the area of provision of extension services, involving general consultancy, problem-solving, process improvement, industrial engineering, quality improvement and others not necessarily requiring laboratory experimentation. Small and medium-sized enterprises (SMEs) in developing countries stood to gain the most from contributions of this type of internal technology transfer, since they were the least likely to be able to afford all of the full-time engineering and technical staff needed to perform the more specialized of these activities in-house. RDIs might need to provide such services initially in order to expedite and facilitate the diffusion of technical change, in the hope that eventually private enterprises would spring up and assume this role.

44. An important dimension of industrial extension services would be of assistance to enterprises in the acquisition and absorption of imported technology. This has occurred in Japan and in the Republic of Korea, where RDIs had played an important role in this regard long before they began to undertake original research. In Taiwan Province of China, where SMEs account for a significant share of manufacturing activity, RDIs have continued to fulfil this function. An illustrative example has been provided by the very successful experience of the Fundacion Chile in Santiago (Chile); its primary function has been to diffuse foreign technology to local users and producers, rather than to concentrate on research as such. A further example of a highly developed system of extension services may be found in Turkey, where liaison units had been set up in the Turkish Scientific and Technological Research Institution (TUBITAC) between RDIs and the productive sector to provide technical assistance. These links in time became a part of the industrial sector, functioning as a sort of "human bridge" linking the two communities.

45. Although the Panel foresaw the provision of extension services as being particularly relevant to enterprises at lower levels of technological capability -- specifically SMEs -- it underscored that enterprises at higher levels of technological sophistication could also benefit. This had been demonstrated by ongoing experience in Denmark.

46. Related to industrial extension was a broad cluster of **supporting services**, such as metrology, setting of industrial standards, testing and quality certification, supply of technical information, market research and the carrying out of economic evaluations. The Panel deemed the supply of such services indispensable for the efficient operation of industry -- particularly for SMEs and other local enterprises aiming at competition in export markets. Normally, such services could be expected to be supplied by separate entities (or, in the case of market research, by enterprises themselves). However, since many

developing countries lacked resources for establishing such institutions separately, the Panel agreed that their functions could be assumed by RDIs. It also recommended that market research and economic evaluations be included among the capabilities of RDIs as a matter of general practice; they would help to meet the needs of enterprises and increase the chances that practical applications would be found for the output of RDIs.

47. **Training** was also an area where RDIs could make a modest contribution towards strengthening technological capabilities, while increasing their interactions with industry. In this connection, the Panel specifically cited the secondment of scientific and technical personnel from RDIs to enterprises or *vice versa* to work on projects of common interest, and thereby improve research and problem-solving skills.

48. The more **classic type of R&D** services comprised product development, materials R&D and application R&D. These ranged from solving immediate practical problems to more long-range, strategic areas of R&D new to the enterprise and which might require laboratory experimentation. These types of services could be offered to enterprises which were evolving their own design capabilities that required product and process development in the laboratory. In such cases, RDIs could be commercially engaged to undertake R&D activities. The Panel stressed that a distinction needed to be made between such commercially supported R&D aimed at solving concrete problems on a demand basis and R&D on generic technologies, such as electronics and mechanical engineering which were of long-term strategic interest to industry as a whole, and which would not be undertaken without public funding. In deciding on the direction and content of future R&D activities, the Panel recommended that RDIs seek, as a matter of course, suggestions and inputs from the enterprise sector at the earliest possible phase of project design, in order to increase interactions between the two sectors.

49. Finally, the Panel noted that some RDIs may have a large enough knowledge base and sufficient expertise to perform **promotional services**. In particular, they could have a potential role to play in identifying and (if requested) approaching potential R&D partners for domestic firms in a position to engage in strategic alliances. Alternatively, they could also be well placed to provide assistance to their countries' foreign investment services in identifying potential foreign investors for certain industries, especially partners for joint ventures.

C. Organizational structure and evolution

50. The Panel recognized that for these and similar activities to be carried out effectively by RDIs, experienced management and dedicated efforts would be required. However, these were likely to be scarce in most developing countries. It was pointed out that the transformation of RDIs would not be an easy process, since the institutional rigidity and high degree of bureaucratization that characterized many RDIs posed a major impediment to their restructuring.

51. The Panel noted that RDIs had frequently been managed by natural scientists who did not possess adequate marketing and management competence. The Panel strongly recommended that RDIs be administered by professionally trained managers who were not in a subservient position to the scientists but on an equal footing with them.

52. To survive in a rapidly changing environment, the RDIs would have to modify some of their basic characteristics and organizational structures to be able to respond to the needs of industry. The Panel recognized the need for differentiated organizational structures to meet the requirements for different types of future services to be offered to the enterprise sector. In some cases, a centralized institutional structure could be more appropriate to deal with the general needs of a particular industrial sector; however, if highly decentralized and more diversified activities were being undertaken, then a more

decentralized structure might be more suitable. The activities and organizational structures of the RDIs would need to be as flexible as possible so that they could perform their functions speedily and efficiently.

53. Moreover, the Panel recommended that future RDI activities might include focusing on particular branches of industry, on certain products/processes or on certain types of services to be offered to industry. In either case, the choice of specialization should correspond to the needs identified by industry itself, i.e. be demand-driven, or end-user driven, rather than supply-driven. Evidently, smaller decentralized types of organizational units would suit specialized services or functions, while larger, more concentrated units would correspond better to more universal, multi-functional purposes. Decisions on the particular organizational structure of RDIs should be taken on a case-by-case basis. Institutions which were intended to encourage and facilitate linkages with production -- such as informal clubs of RDI clients and specialized autonomous units undertaking R&D activities for a particular purpose and operating within the institutional framework of the RDIs -- were proposed as possible institutional innovations. The Chilean club of R&D users, within the Instituto de Investigaciones Tecnologicas (INTEC) had provided a forum for exchange and learning between the business community and RDIs. Such arrangements could be very informal and required little resources from the RDI, but their very successful outcome for the Chilean packaging sector (made up of 35 enterprises) had paved the way for similar types of arrangements to be made for the promotion of the microelectronics sector and total quality management.2/ Other informal organizational arrangements of a similar nature aimed at linking business with the sources of R&D had enhanced R&D's contribution to Chile's business sector. Similarly, the Malaysian Institute for the Growth of High Technology (MIGHT) represented a more institutionalized arrangement than that of the clubs of R&D users, but with quite similar objectives.

III. STRENGTHENING R&D IN THE ENTERPRISE SECTOR

54. Attention was devoted to various types of measures for promoting greater R&D in the enterprise sector. The Panel agreed that in both developed and developing countries, the rationale for stimulating enterprises to invest more in R&D was that returns to the country from such investment -- arising from the resultant increase in productive efficiency or new or improved products -- exceeded what enterprises were able to appropriate for themselves in the form of profits.

A. General and selective measures of public policy to promote enterprise-based R&D

55. The Panel divided its discussion between general and specific measures for stimulating R&D. **General measures** to promote enterprise investment in R&D had the advantage of being simple to administer and available to all, or at least, to large categories of enterprises on the basis of simple criteria that required little, if any, administrative discretion. Such measures consisted of various types of fiscal instruments, *inter alia*, tax incentives, levies, exemptions and write-offs of R&D investments from income tax liabilities, accelerated depreciation and custom-duty exemptions on imported machinery and equipment, especially laboratory equipment.

56. The application of subsidies to stimulate R&D constituted another type of public policy instrument. Such measures as subsidized loans, loan guarantees and project grants could be particularly effective in this respect. Other measures included subsidized services or inputs (energy, building space) as well as duty exemptions on imported equipment and other inputs used in R&D activity (as already mentioned). Governments could also set up technological funds based on low-interest loans for funding R&D and related technological expenditures.3/

57. The Panel furthermore suggested that public R&D contracts (of which at present a large percentage went for military purposes) be re-directed towards civilian uses, particularly in the industrial sector. Preferential treatment could be granted for bids that contributed to demand for local technological improvement or R&D.

58. The Panel agreed that the mechanism, suggested in paragraph 47 above in connection with RDIs, could be generalized to include research fellowships for scientific and engineering personnel in industry. Such personnel could be offered the opportunity to study or work abroad, in other firms or in TNCs. Other similar measures that encouraged mobility could serve as a channel for greater mobility of engineers and scientists. In Malaysia, for instance, the Government had taken steps in this direction by encouraging personnel from RDIs to obtain employment in the private sector, both in Malaysia and abroad and/or to set up their own firms.

59. The possible disadvantages of general measures stemmed from the fact that, since they were available to broad groups of enterprises, the cost in terms of foregone tax receipts (or diverted resources in general) might be quite high. All firms would benefit equally regardless of how deserving they might be.

60. **Selective measures** for the stimulation of enterprise investment in R&D involved the targeting of particular industries and even firms within industries (see TDR, 1994; Hillebrand, 1994). These could include the same kinds of fiscal incentives and subsidies already noted in section I. To these could be added preferential credit facilities, access to import licensing and other mechanisms which create rents for individual firms or industries. However, in order to be effective, such measures should be accompanied by a system of continuous policy evaluation -- an area difficult to control. Preferential support for R&D in certain sectors such as airframe construction, electronics and biotechnology had been used extensively in a number of developed and developing countries.

61. The advantage of selective measures was that they allowed the government to concentrate resources on those industries, product groups, or firms which showed what was the greatest promise in terms of long-term growth prospects, financial viability and competitiveness.

62. Citing the example of the Republic of Korea, the Panel agreed that targeting of particular industries and industry groups could considerably accelerate the pace of technological development. The Government of the Republic of Korea had offered a package of promotional measures to more innovative companies with a view to developing their export capabilities. In Germany, where publicly funded R&D exceeded private R&D, it was noted that a fair proportion of public R&D was used to induce R&D in the private sector. It was further noted that the German system of innovation consisted of a mix of general and selective measures, with the Government supporting specific, mission-oriented R&D. In this connection, the German Government exercised selectivity by first defining certain strategic sectors (such as materials' technology and microelectronics) and subsequently stimulated R&D in them through preferential credits and other instruments. The Panel observed that, in the United States, R&D was also subsidized heavily (either directly or indirectly), particularly in the military sector, but increasingly in industries dominated by new technologies such as those of California's "Silicon Valley". The Panel noted furthermore that in all OECD countries, R&D was predominantly mission-oriented and that despite some past mistakes, this continued to be so in the hope that some errors would not be repeated in the future.

63. In order to encourage technological "leap-frogging" progress, the Panel recommended a selective approach for developing countries, especially in industries where the international race for technological advances had become more competitive. In the case of Singapore, for example, the Panel noted that the Government had adopted an approach based simultaneously on focus and flexibility; there was a focus on basic generic technologies, particularly in

biotechnology, information technologies and microelectronics; yet there was flexibiltiy in choosing the appropriate product niche and this choice was determined by the market.

64. The Panel observed that the argument against more selective measures pointed to the inefficiencies associated with government intervention, crowding-out of the private by the public sector and past errors associated with wrong choices of "winners", as had occurred in the case of shipyards in Denmark, high definition TV in Japan's consumer electronics industry and oil shale development in the United States. Furthermore, the selective approach, which targeted specific industries, pre-supposed the existence of a well-trained, technically competent bureaucracy capable of choosing rationally and in the public interest between competing beneficiaries for government largesse. The bureaucracy that might be created to manage such a system could be expensive and become corrupt and self-perpetuating.

B. Government as promoter

1. R&D and SMEs

65. Traditionally, in the enterprise sector, it was the large-sized firms that had undertaken most of the R&D. SMEs generally made little or no investment in R&D. However, there was a need to focus on SMEs in the innovative process. In this connection, the successful experiences of conglomerations of highly specialized SMEs in traditional industries of more industrialized countries should be noted (see UNCTAD, 1994b). The Panel recommended the promotion of technological collaboration, unrestricted by national borders, between SMEs and institutions that specialized in the generation of technological knowledge, as a means of transforming traditional industrial clusters into modern industrial districts.

2. Promotion of technological cooperation through R&D

66. Inter-firm relationships had changed dramatically in recent decades. Industrial firms were finding it necessary to cooperate both vertically with suppliers and customers and horizontally with erstwhile competitors. Three factors in particular accounted for the emergence of this phenomenon. First, the introduction of new products and processes involved the interaction of several different types of technology and each firm had more knowledge in some areas than in others. Second, the high absolute cost of R&D often made it prudent to share costs among several firms. Third, customer-supplier coordination had become part of product development, marketing and other activities with an R&D component, as the increasingly high costs of R&D could be shared through closer inter-firm technological collaboration.

67. Governments could promote inter-firm collaboration in R&D by facilitating transfer of technology between firms and assisting in the formation of national and international strategic alliances, collaboration agreements and/or technological parternships.

68. The Panel affirmed that governments could assist in the establishment of joint ventures, consortia and other types of cooperative links between enterprises and others with the participation of universities and local governments. In Italy, such collaboration had included partnerships with technologically advanced companies for the exploitation of scientific discoveries (see Malerba, 1993).

69. Other means of support for R&D cooperation between firms existed, including the relaxation of regulatory constraints and innovative means of funding. In the Republic of Korea, for example, an R&D fund had been set up uniquely to support cooperative R&D projects and only those firms undertaking joint R&D projects were eligible to apply. Another approach involved the use of matching

grants, whereby the Government provided the initial seed money for certain projects that were later matched (or exceeded) by resources from the private sector. Such mechanisms had frequently been used in the United States and Italy to promote enterprise-based R&D, frequently within universities.

70. Another mechanism to promote R&D in the enterprise sector consisted of levies for R&D. This entailed the creation of a fund for R&D by taxing individual private firms, on a consensual basis, for the purpose of supporting a particular R&D venture of particular interest to a given industry or group of industries. The advantage of such schemes was that they made it possible to circumvent the problem of "free-riders", which would benefit without investing, while making it possible to finance an activity such as training for R&D without the need for an unduly large investment expenditure by any one party. This type of mechanism had worked well for Kenyan coffee and tea growers and producers, who had benefited from the results of an initiative of the Coffee and Tea Research Associations that had been supported by a one per cent levy on farmers. It was also noted that, in Singapore, the levy system, which had been considered, was not applied because the Government deemed that a general levy would be unfair to firms at disparate levels of technological development.

3. Risk capital

71. Apart from measures to promote enterprise R&D as discussed above, there was also a need for more effective mechanisms to be put into place to encourage investment in risky R&D. In this connection, the Panel reiterated the importance of creating an appropriate enabling environment for investment in R&D (as discussed in paragraphs 28 to 30 above). Although a favourable investment climate was necessary, it was not sufficient, however, in itself to induce business interests to devote large resources to R&D and new processes and products with uncertain outcomes. There was a need for venture capital firms and other specialized institutions, such as innovation banks, which could specialize in the provision of the kind of high-risk funding generally associated with some kinds of R&D. Very frequently, it was wealthy private individuals, or "angels" who invested their own resources to finance investment R&D.4/ Favourable taxation policies to create incentives for such investors merited consideration. However, it was necessary to enact appropriate legislation and regulations for venture capitalists, in general, so that they could not impose unduly hasty liquidations that might threaten the survival of the fledgling enterprise.

4. Transnational corporations (TNCs) and R&D

72. The Panel agreed that a key determinant in the firm's capability to access generic, science-based technologies was the degree of openness of its country's research system to links with TNCs. As a rule, TNCs preferred to concentrate their R&D activities in the home country while little, if any, R&D took place in developing host countries. However, in recent years, some TNCs had been locating a part of their R&D activities in their foreign affiliates, collaborating with regional research organizations or academic institutions abroad as well as pooling together their R&D resources in joint ventures with other firms. For example, several large TNCs had been performing some of their strategic R&D in East European countries in order to exploit cost advantages in the form of relatively lower salaries for scientists and engineers (see Reddy, 1993). Although it was still too early to ascertain whether recent isolated examples of this represented a genuine trend, the potential implications for technological development in developing countries looked positive.

73. The experiences of many countries indicated that TNCs had the potential to contribute substantially to the accumulation of local technological skills and capabilities through foreign direct investment. One of the ways to make the most of this potential could be to facilitate their carrying out R&D in host countries. It was noted that Canada (although it was not a developing country) had succeeded in obtaining the agreement of General Electric and other TNCs to

undertake part of their R&D locally as a condition for approval of their investments.

5. Role of intermediaries

74. The Panel agreed that, in many cases, the dissemination and commercialization of research output required the involvement of an intermediate institution. Intermediaries, such as chambers of commerce and industry associations, had an important role to play in promoting enterprise collaboration and could assist enterprises in opening up to R&D. Furthermore, dissemination of knowledge and skills at the community level could require the involvement of community organizations, NGOs or local opinion makers. The role of intermediary institutions thus needed to be further explored in the promotion of R&D linkages and the setting of priorities.

6. University-business cooperation

75. The idea of enterprise-sector collaboration with universities, TNCs and other sources of technological collaboration (external to the firm) merited support. The United States was one example of a country in which such linkages formed the backbone of the national R&D system.

76. Generic or "blue-sky" research, without immediate applications, should remain publicly funded and within the university setting, it was felt. University-business links should be encouraged, in principle, but should be well-monitored. The setting up of specialized research units associated with, but organizationally separate from, universities in which university staff could participate should be pursued.

77. There were inherent dangers in university-business collaboration in that competition could arise between academic responsibilities and the demands of contract-based research. To avoid such conflict, limits needed to be set on the amount of time devoted by teaching staff to contract research as well as protecting the right of publication of the results of contract-based R&D projects.

IV CONCLUSION AND RECOMMENDATIONS

78. The Panel's overwhelming conclusion was that, owing to the weak performance of industrial sectors in developing countries, their R&D had a more broadly defined mission to fulfil than in developed or some newly industrializing countries where the emphasis was on laboratory experimentation aimed primarily at the generation of product and process innovations. The main task of R&D efforts in the majority of developing countries and many of the countries in transition was to contribute to the transfer, adaptation and diffusion of imported technologies as part of an overall effort to upgrade the domestic capacity to conceive and carry out investments, operate and maintain production facilities, implement design improvements and market goods and services.

79. To this end, the Panel recommended for these developing countries and countries in transition the pursuit of a three-pronged strategy, consisting of the creation of an enabling environment for R&D (see section I above), transformation of RDIs to make them more responsive to the technological needs of the industrial sector (see section II) and stimulation of enterprise-level R&D activities through a combination of general and selective measures (see section III).

80. The Panel recommended to the Commission that it take up the following in its future programme of work:

(a) Examination of the relevance of the experiences of successful RDIs for developing countries and countries in transition;

(b) Exploration of the merits of alternative instruments for the promotion of enterprise-level R&D;

(c) The carrying out of national reviews of S&T policies on a regular basis; and

(d) Study of the feasibility of establishing regional or sub-regional venture capital funds.

NOTES

1/ The notable exception in this regard may be found in some Egyptian RDIs, where researchers are personally rewarded for their innovative endeavours.

2/ The club of R&D users in the packaging sector in Chile, associated with INTEC, sprang from informal arrangements between SMEs in the packaging sector which pay a fee to belong to the club. The fees were subsequently paid to INTEC in exchange for some extension services it had provided to the SMEs.

3/ A description of Brazil's efforts in this regard was contained in UNCTAD, *Ad Hoc* Working Group on Interrelationship between Investment and Technology Transfer, "Country case study submitted by Brazil" (TD/B/WG.5/Misc.22), third session, Geneva, 21 March 1994.

4/ "Angels" may be, *inter alia*, doctors, lawyers, affluent widows, etc., who can be persuaded, because of family connections and personal friendships, to invest their own resources in risky, new industrial ventures. If the venture is successful, they may share in the profits.

REFERENCES

ALBORNOZ, M. (1994), La Vinculacion Universidad - Empresa en America Latina, consultant's report, UNCTAD, Geneva.

ESCWA (1993), "The evolution and integration of research and development vis-à-vis industrial enterprises", in The Integration of Science and Technology in the Development Planning and Management Process in the ESCWA Region (E/ESCWA/NR/1993/15), 1993.

GABRIEL, A., M. HEMPEL, W. HILLEBRAND, D. KRULL, K. MEYER and F. WOEMER (1992), Technological Modernization in Small and Medium Industries in Korea with Special Emphasis on the Role of International Enterprise Cooperation, German Development Institute, Berlin, 1992.

GERYBADZE, A. (1994), Efficient Networking and Technology Transfer: Managing the Interface between University, Research Institutes and the Industrial Sector, paper prepared for the Panel on the Contribution of Technologies, including New and Emerging Technologies, to Industrialization in Developing Countries (24 and 25 October 1994, Geneva).

HILLEBRAND, W. (1994), Strengthening Technological Capability in Developing Countries: Lessons from German Technical Cooperation, paper prepared for the Panel on the Contribution of Technologies, including New and Emerging Technologies, to Industrialization in Developing Countries (24 and 25 October 1994.

LATIF, A.-F.A., and **A.I. NAGUIB** (1990), Science and Technology in Africa - A Case Study from Egypt, ASRT, Cairo, Egypt.

MALERBA (1993), "The national system of innovation: Italy" in Nelson, R.(ed.), National Innovation Systems: A Comparative Analysis, Oxford University Press, Oxford.

MATACHE, G. (1994), Strengthening of Linkages between R&D and the Industrial Sector in Developing Countries, background paper prepared for the Panel on the Contribution of Technologies, including New and Emerging Technologies, to Industrialization in Developing Countries (24 and 25 October 1994, Geneva).

MAYA, R.S. (1990), Science and Technology in Africa - A Case Study from Zimbabwe, Zimbabwe Institute of Development Studies, Harare.

MLAWA, H.M., and **M.S.S. MOHAMMED** (1993), Profiles of R&D Institutions in Tanzania - Managing the Interface amongst the Scientific and Technological Research, Public Policy and Productive Structures, a country report on the United Republic of Tanzania, prepared for the Presidential Forum, Gaborone, Botswana.

MWAMADZINGO, M. (1994), Industrial Research Institutions and their Interaction with the Productive Sector: Global Myth and Empirical Evidence from Kenya, paper prepared for the Final Workshop of the Kenya Industrial Research Project of the Department of Economics, University of Nairobi, Kenya.

REDDY, P. (1993), New Trends of Locating Corporate R&D in Developing and East European Countries by Transnational Corporation and their Implications, consultant's paper prepared for UNIDO, Vienna, July.

THULSTRUP, E.W. (1994), Scientific Research for Development, Human Resources Development and Operations Working Paper, no. 25, World Bank, Washington, D.C.

UNCTAD (1989), Promotion and Encouragement of Technological Innovation - Technological Innovation Policy in France: Measures and Instruments Chosen (UNCTAD/ITP/TEC/1), Geneva, UNCTAD.

UNCTAD (1990), Research and Development Institutes in Developing Countries and their Contribution to Technological Innovation (UNCTAD/ITP/TEC/11), Geneva, UNCTAD.

UNCTAD (1992), R&D Collaboration Agreements among Enterprises: A Legal and Contractual analysis (UNCTAD/ITD/TEC/2), Geneva, UNCTAD.

UNCTAD (1993), From Technological Competence Building to Competitiveness: Challenges for Publicly Funded R&D in India - A Case Study of the National Chemical Laboratory, Pune (UNCTAD/ITD/TEC/10), Geneva, UNCTAD.

UNCTAD (1994a), Trade and Development Report 1994 (UNCTAD/TDR/14), Geneva, UNCTAD.

UNCTAD (1994b), Technological Dynamism in Industrial Districts: An Alternative Approach to Industrialization in Developing Countries? (UNCTAD/ITD/TEC/11), Geneva, 1994.

UNCTAD (1994c), Country Case Study, Brazil (TD/B/WG.5/Misc.22), Geneva, UNCTAD.

UNIDO (1993), Technology and Industrialization - Revitalization of Industrial Growth in Developing Countries, Vienna, April: paper prepared for the first session of the Commission on Science and Technology for Development, New York, April 1993.

UNIDO (1994a), Strengthening of Linkages between the National R&D Systems and the Industrial Sector in Developing Countries, note prepared for the Panel on the Contribution of Technologies, including New and Emerging Technologies, to Industrialization in Developing Countries (24 and 25 October 1994, Geneva).

UNIDO (1994b), Strengthening of linkages between R&D and industrial sector in developing countries, UNIDO note prepared for the Panel on the Contribution of Technologies, including New and Emerging Technologies, to Industrialization in Developing Countries, Geneva (based on a UNIDO report by Mr. A. Araoz).

WONG, P.K. (1992), "Development of national technological capabilities in Singapore: past strategy, future management challenges" in Integrating Technology and Management: A Tripartite Approach, Proceedings for PECC S&T Task Force Workshop, Jakarta 1992.

ANNEX

The Panel met in Geneva on 24 and 25 October 1994 and was chaired by Mr. M. El-Halwagi (Egypt). In addition to Mr. El-Halwagi, the following three members of the Commission on Science and Technology for Development (CSTD) participated in the Panel:

Mr. N.E. Busch (Denmark)
Mr. W. Hillebrand (Germany)
Mr. G. Matache (Romania).

The meeting also benefited from the participation of representatives of international organizations, namely, Mr. I. Ahmed (ILO) and Mr. A. Bromley (UNIDO) and the following international experts:

Mr. S. Escudero (Chile)
Mr. A. Gerybadze (Switzerland)
Mr. D. James (United States)
Mr. S. Mukerji (Canada)
Mr. M. Mwamadzingo (Kenya)
Mr. P-K. Wong (Singapore)

The Panel was assisted by the Division of Science and Technology of the UNCTAD secretariat.